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Dynamics of meandering spiral waves with weak lattice perturbations

Spiral waves are observed in many different situations in nature, perhaps most importantly in excitable electrophysiological tissue where they are believed to be responsible for pathological conditions such as cardiac arrhythmias, epileptic seizures and hallucinations. Mathematically, spiral waves occur as solutions to systems of reaction-diffusion partial differential equations which are frequently used as models for electrophysiological phenomena. These equations are invariant with respect to the Euclidean group $SE(2)$ of planar translations and rotations. In reality however, Euclidean symmetry is at best an approximation. Inhomogeneities and anisotropy in the medium of propagation of the waves break the Euclidean symmetry, and can lead to such phenomena as anchoring and drifting. In this paper, we study the effects on quasi-periodic meandering spiral waves of a small perturbation which breaks the continuous $SE(2)$ symmetry, but preserves the symmetry of a regular square lattice. Our main results are on the effects of lattice symmetry-breaking on respectively quasi-periodic meandering waves, on meandering waves whose meander path is a closed epicycle (we pay special attention to phase-locking in this case), and on modulated travelling waves. In each of these cases, we give the main mathematical results, give an interpretation for how these mathematical results translate to dynamical features of spiral waves, and then illustrate with numerical results performed on FitzHugh-Nagumo system for various choices of inhomogeneity functions, and various kinematic parameters.